Bioclimatic air conditioning system for typical apartment building

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1. INTRODUCTION

Since ancient times man has always tried to control the environment in which he lived. Principles of environmental building design where developed over the centuries mostly by trial and error. One early form of environmental design was the atrium, which can often be seen in houses of wealthy Romans (Fig. 1). It's one of the - if not *the*- simplest way of keeping the inside of the building warm during the winter, cool during the summer while letting the sun enter inside the building at the same time. However, even in our days many environmental-friendly solutions are not able to be applied in modern cities.

Figure 1: Roman Atrium.

2. THEORY

In traditional environmental building design the cooling of the building is achieved by the flow of the outside air through the building. The cooler outside air supplants the inside one thus dropping the temperature of the building.
In modern cities, especially in their centers, the advantages of such a function can be transformed into serious problems. One of them, and the most important one, is the harm that can be caused to the health of the occupants by inhaling the by-products of internal combustion engines, mainly HC, CO, NOx, an others.

The necessity of filtering the air that the users of a building inhale is great. However, the addition of a filter to the air channel system that brings outside air into the building reduces its cooling capability.

In Greece, there are many cities where great concentrations of HC, CO and NOx is detected. Most of the buildings need a system that cools and filters their inside micro-environment at the same time. The usual solution is a common air-conditioning system that is placed on the outside wall of each apartment. The massive use of those systems certainly cool the building, but they use lots of energy and give off great amounts of heat back to the environment in an unpremeditated way because the heat exchangers are all over the building surfaces. The hot air that practically surrounds the building is trapped in the city's air channels and goes away only when cooler air comes. In order to have a comfortable urban environment, the city's air channels must let the local winds flow through the city freely. Differently the urban environment not only suffers by the polluted air but by the

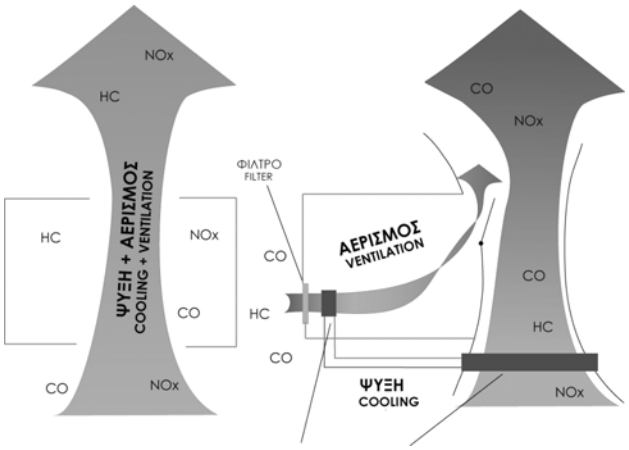

Figure 2: Traditional (left) & proposed (right) method of building cooling.

higher temperature as well.

3. DESIGN

This study was done on the example of a typical five-storey apartment building that is located in the center of a heavily air polluted Greek city and which was not designed bioclimaticly. The main view faces the north where there is a five-metre wide road with buildings on both sides. Eastwards and westwards, the building is in contact with buildings of the same height and southwards it has the shortest distance from the other building that law permits. The local winds are mainly northern.

The aim was to design a system that takes advantage of the micro-environment's thermodynamics around the building in order to cool its interior spaces during the summer and heat them during the winter. Its structure must not be part of the building's structure but must have the ability to be detached without leaving scars to the building.

It is important to mention here,though, that the following proposed system is designed to work in Mediterranean environments.

3.1 Design Principles

The system in question uses a different way of pushing filtered air inside the building from the methods commonly used. Traditionally, the bioclimatic systems that use air for cooling, base their operation on the air flow over the surfaces (Fig. 2). The efficiency is higher as the speed of the air-flow rises. The placement of a filter reduces the air speed and therefore the efficiency of the whole operation, as mentioned before. That's why another method must be used to achieve the same result.

The proposed method function is almost similar to the water-cooling system of a car engine: The air flows through the radiator, which consists of small cells, and cools the coolant which runs through those cells, it gets cooler and then it is pumped through the hot engine. The engine exchanges temperature with the liquid, and as a result, the former gets cooler and the latter gets hotter. This procedure is repeated continually (Fig. 2).

In the bioclimatic air-conditioning system the "engine" is the inside of the building and more specifically each apartment separately. The main difference is that the aim of this system is to 'feed' the apartments with fresh filtered cooled air rather than making a "water cooled apartment" without refreshened air.

It also differs from the traditional bioclimatic air cooling building applications on the user's choice to decide whether they want to cool or heat their house without affecting the efficiency of the system.

3.1.2 Cooling System

This system uses two different air channels for the cooling process (Fig. 3). In the first channel the environment's - polluted- air flows all the time through a duct. The second one which also flows through another duct, brings filtered air from the outside environment. In turns, it can circulate the existing inside air. Those two exchange their temperatures with heat exchangers. While the first one cools the heat exchanger all the time, it is up to the apartment's users to decide weather they want to utilize it or not, by activating the second one. In this way there is sufficient energy always available for the cooling process to take place.

In particular the first channel uses the method of solar chimney for its air flow. The end part of the duct where the air from the first channel flows is placed above the 5^{th} floor. It is made out of a high- heat capacity and conductance so it can absorb as much solar energy as it can. The winds help its function by increasing the low pressure at the upper end of it.

At its lower end, lies the inlet of the outside environment air. After the inlet, follows a rectangular venturi structure (Fig. 4). The air speed rises, the pressure and temperature falls. At that

place there are thin vertical radiators with very large surfaces placed in parallel with the air flow. Each radiator serves one particular apartment. The radiators are placed inside the venturi tube because with smaller radiators one can achieve the same result as with larger ones but with no venturi tube. As the air flow leaves the radiator, it turns upwards 90º and rises until it exits the duct.

The liquid that was cooled by the radiators is then pumped up to the apartments.

The second air channel is not common for

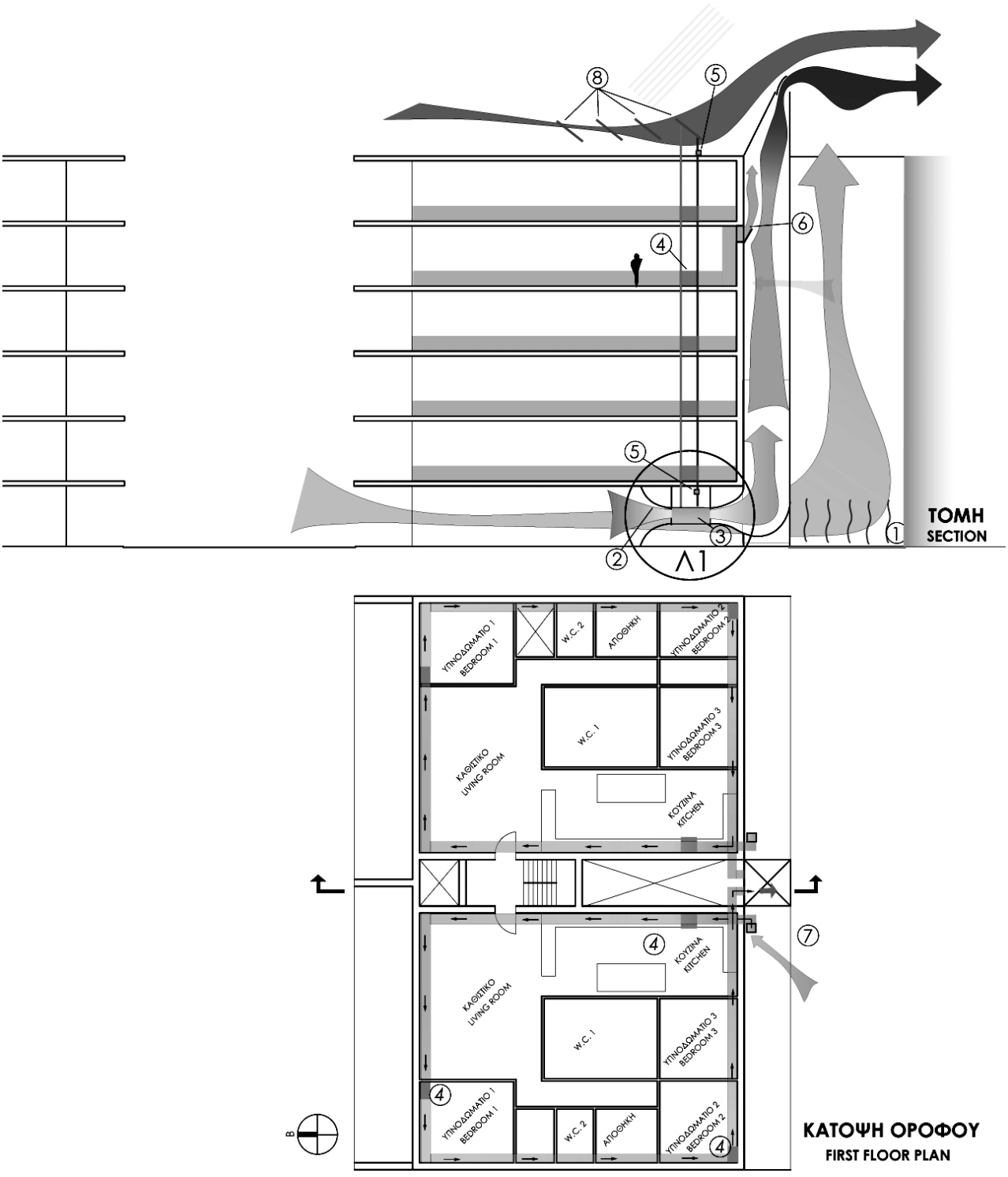

Figure 3: Section and floor plans of the building and the bioclimatic air conditioning system.

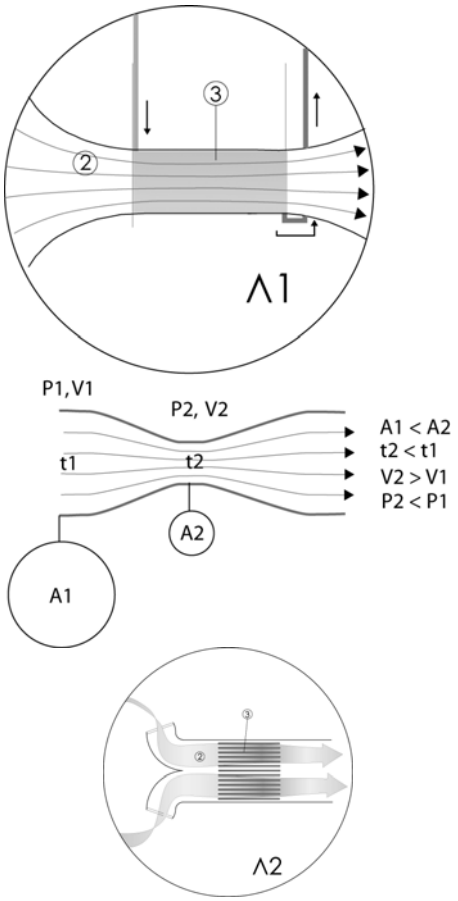

Figure 4: Details of venturi's tube and its function.

the whole building. Each apartment is fitted with a separate circuit which has no connection with those of the other apartments. The start of the circuit brings the outside air inside the apartment while its end has a flap which separates it from the first channel. The air starts moving by opening the flap which is placed in such a way that, when it is opened, low pressure generates at the end of the second air channel because of the air flow of the first one. The result is that air enters from the environment to the second channel and is finally sucked from the first one. When the air enters the second channel, it flows through a filter so that it can be cleaned. The air runs around the house through air ducts just like the common central air conditioning system. The air is not already cooled but this is done by placing heat exchangers throughout the circuit wherever this is needed. The coolant from the radiators of the first channel goes to these heat exchangers and the result is to cool the filtered air that comes form the environment.

However another flap can cut off the supply of outside air and circulate the air that is already inside each apartment while filtering it.

Finally, in the northward side of the building where the first channel duct is, hot air may be trapped. In order to avoid this effect, there is a shallow cistern with water, which helps a lot during days with low humidity.

3.1.3 Heating System

The heating process does not use the first air channel. Solar panels that are placed on the roof have a common circuit with the coolant that is used for the cooling process. The flow from the radiators stops in order to circulate from the panels to the heat exchangers only. The panels warm the coolant which exchanges heat with the second air channel through the heat exchangers which are the same as those used for the cooling process.

3.1.4 Ventilation System

When no cooling or heating is needed only the ventilation system works. It functions in the same way as the cooling system, with the exception that the cooling process does not take place. The coolant does not flow and no heat exchange takes place in the second channel.

However there is a penalty of drag in the first channel imposed by the existence of the unnecessary radiators used for the ventilation. The function of by-passing the radiator by adding a flap behind it so that forced air will enter the first channel, increases the system's complexity dramatically. If one user wanted to turn on his cooling system and another one only wanted to ventilate his apartment, the first channel should consist of many sub- channels functioning independently of one another, each of them should be controlled from the corresponding apartment.

When the solar chimney cannot work sufficiently a two-stage-pitch fan that is placed on the entry of the filtered air begins to work so that air will enter the second air channel.

The cost of constructing so complex a system would not justify its benefits.

3.2 Soundproofing / Heat-proofing

Common air sound traps cannot be used because they produce too much turbulence to the air flow. Soundproofing can be achieved by making the first air channel pipe double shelled and the gap between the two walls filled with non toxic

foam or fabric material as well as by attaching it with vibration absorbing mounts to the building.

Heat proofing is needed on the upper floors so that the high-heat-capacity material of the solar chimney should not be able to transfer heat to them. The high-heat-capacity material covers only areas of the solar chimney that has no visual contact with the balconies so that no heat can be emitted. A third empty shell is added at the sides where no high- heat-capacity exists. It will extend from the start level of the 4^{th} floor to the top end of the 5^{th}. It will have a layer of reflective aluminum in the inside face. The air will enter at the bottom and, because of the heat, it will rise and exit forming in that way a natural insulation. The heat of the solar chimney's material will make it even hotter and it will rise faster, away from the upper floors.

4. BENEFITS

The bioclimatic air- conditioning system achieves the following benefits :

1. By using the bioclimatic principle, minimum energy is required for heating and cooling. The only parts that need energy are the coolant pumps and the two- stage-pitch fans.
2. No Freon or other chemicals, harmful for the environment, are used.
3. The potential of the system is always as high as the solar and wind energy allows and the efficiency of the cooling and heating process does not depend on the number of the apartments that use it.
4. The by- product of the system, which is only heat, is delivered to the environment in a premeditative way.

Many buildings that have this system in a city make the heat not to reflect to other buildings but to rise above the buildings and in this way to force new air to come and replace it. So, a continuous renewal of air takes place over the city, which is very important in air polluted environments.